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Spin-Echo and Gradient-Echo EPI of Human Brain Function at 3 Tesla

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PURPOSE:

Spin-echo and gradient-echo echo planar imaging (EPI) of human brain function at 3 Tesla is demonstrated and compared with results obtained at 1.5 Tesla.

INTRODUCTION:

The presence of paramagnetic deoxyhemoglobin in the vasculature creates microscopic field gradients which cause intravoxel dephasing. As the amount of deoxyhemoglobin is decreased by brain activation induced vasodilatation, transverse relaxation rates $\Delta R2$ and $\Delta R2^*$ decrease, causing localized signal enhancement in T2* and T2-weighted pulse sequences. Previous work has demonstrated that higher field strengths are more sensitive to susceptibility effects, therefore stratifying the activity induced signal change related to subtle changes in blood oxygenation (1, 2). Furthermore, the static, (T2*-related), and diffusive,(T2-related), intravoxel dephasing mechanisms scale differently with field strength (2), making it unclear as to exactly how field strength affects blood oxygenation level contrast. In this study, comparisons are made between 1.5 and 3 T regarding the measured parameters of activation induced $\Delta R2^*$, $\Delta R2$, and $\Delta R2^*/\Delta R2$.

METHODS:

Imaging was performed on a Bruker Biospec 3T/60 and a GE 1.5T Signa magnet. A 30 cm i.d three-axis, balanced torque, local gradient coil, designed for rapid gradient switching, is used in both systems. At 3 T, a band-pass quadrature endcapped birdcage transmit - receive coil is used. At 1.5 T, an elliptical endcapped birdcage transmit - receive coil is used. For both field strengths, sampling time is 8 us per IQ pair and the readout window is 40 ms. Time courses of 100 sequentially obtained single - shot 64 x 64 resolution gradient-echo and spin-echo images were made on the same subject and of essentially the same axial slice (5mm thickness) through the motor cortices. TE = 40 ms in the gradient-echo sequence and 100 ms in the spin-echo sequence. TR = 1 sec. FOV=24 cm. During the time course, the subject performed a motor cortex activation paradigm of self-paced bilateral finger movement during two 20 second episodes. Measurements of $\Delta R2^*$ and $\Delta R2$ are made from regions showing activation in both spin-echo and gradient-echo sequences.

RESULTS:

Changes in relaxation rate are calculated by averaging images during activation and rest then calculating $\Delta R2(^*) = -\ln(Sa/Sr)/TE$, where Sa and Sr are the active state and resting state signals respectively. In this study, at 1.5 T, activation induced $\Delta R2^* = -.70 \pm .08\ s^{-1}$, $\Delta R2 = -0.24 \pm 0.02\ s^{-1}$, and $\Delta R2^*/\Delta R2 = 3.58 \pm .43$. At 3 T, $\Delta R2^* = -1.29 \pm .27\ s^{-1}$, $\Delta R2 = -.45 \pm .06\ s^{-1}$, and $\Delta R2^*/\Delta R2 = 3.60 \pm 0.65$. To demonstrate the improvement in functional contrast in both spin-echo and gradient-echo sequences, the time courses from ROI's in the same region of the brain are shown. Figure 1 compares the gradient-echo sequences (TE = 40ms) and Figure 2 compares the spin-echo sequences (TE=100ms). It is noted that isolated pixels showed signal increases of up to 40% in both the spin-echo and gradient-echo sequences at 3T, while the maximum signal change at 1.5T was in the range of 8%. It is also noted that, at the TR used, a small fraction of additional T1-related enhancement may be present since T1 of blood water increases with field strength.

Because one gains more sensitivity to subtle changes in blood oxygenation at higher field strengths, it is hypothesized that "physiological noise" (i.e.: baseline fluctuations in blood oxygenation) will become more significant at higher field strengths and may ultimately set the upper limit on the delectability of activation induced signal enhancement. Physiological noise was assessed by comparing the standard deviations of the signal in gray matter and in areas of pure noise during the time course. For both 1.5 T and 3 T, noise in the time course series was generally 30 to 50% higher in the gray matter than in regions having no signal.

CONCLUSIONS:

Spin-echo and gradient-echo echo planar MRI of human brain function using blood oxygen level contrast is demonstrated at 3 Tesla. The results show that the activation induced relaxation rate changes are field strength dependent. Two problems that arise at higher field strengths are an increased difficulty to obtain a sufficient shim over a large volume and the decrease in intrinsic tissue T2*. Nevertheless, our preliminary results indicate that at 3T, functional contrast to noise is improved.

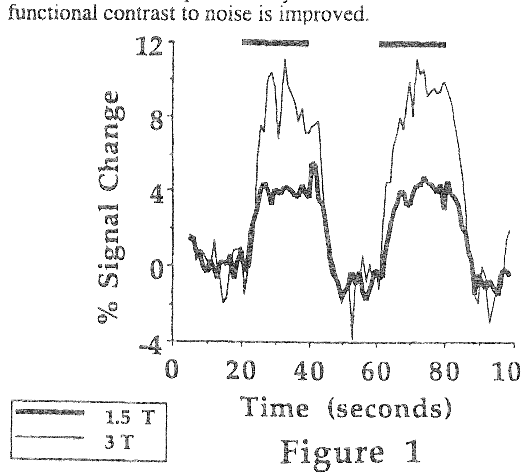

Figure 1

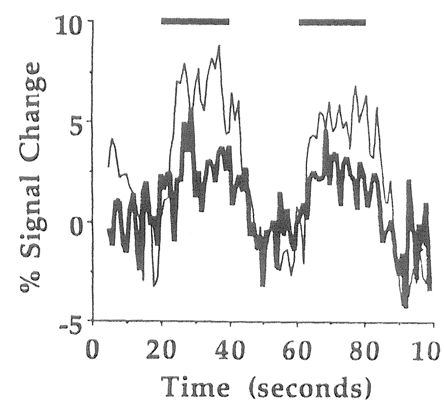

Figure 2

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